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Light Reflectivity of Multiwall Carbon Nanotubes with Pattern-less or Pattern-grown Nanotubes

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Abstract. The light reflectivity of multiwall carbon nanotubes (MWCNTs) in the 1150nm - 1755 nm wavelength range with pattern-less and pattern-grown nanotubes are studied. From test measurements it concludes that when the multiwall carbon nanotubes are pattern-grown fabricated its return loss is linearly proportional to the nanotubes grown height and consequently the pattern-grown CNTs can be implemented as a good optical attenuator. However for high density nanotubes fabricated with pattern-less process it has greater than 45 dB return loss, this is equivalent to have less than 0.56% reflectivity; with this high absorption effect it can be utilized as a black body absorber.

Introduction

In recent years, carbon nanotubes (CNTs), with their unique one-dimensional π-electron conjugation, mechanical strength, and high thermal and chemical stability, make them very attractive for use in many applications [1-4]. In this paper the fabrication of multiwall carbon nanotubes in different heights with pattern-less and pattern-grown processes are considered; their reflectivity and other characteristics are investigated and their possible applications are proposed.

The fabricated of two types of carbon nanotubes, namely CNT with patterns and patterns-less, and their characteristics measurements, are considered. The pattern-grown nanotubes are fabricated with photolithograph technique, it is a circular phase array with a diameter of 50 μm and the distance between circular centers is 80 μm as illustrated in Fig. 1. Its area is 1cm×1cm and it then uses the sputtering system to deposit the metal catalyst Co-Ti(40 Å) / Ti(10 Å) / Al(100 Å) and then it uses acetone in the lift-off process; finally the thermal chemical vapor deposition (CVD) is used to grow the nanotubes[5]. However it does not implement the photolithograph process in the fabrication of pattern-less nanotubes but it needs to control the grain size of the metal catalyst to complete the fabrication of high density grown nanotubes.

A black body is a material with the characteristics that no optical source can penetrate through or reflect from it and consequently it can absorb all optical sources incident on it and converts the incident energy into heat and can be utilized as an ideal heat radiation source. With this unique characteristic makes the black body been utilized in the applications involving the conversion of light into heat as a collector of solar energy [6-12] or be used as a heat detector for infrared [13-15]. In [16-18] it fabricated nanotubes with single wall structure and from measurements it could attain 98-99% absorption rate that is better than any products built from composite materials. In our fabrication when it uses high density pattern-less multiwall carbon nanotubes as a reflector, its absorption rate is better than any products fabricated from single wall carbon nanotubes.

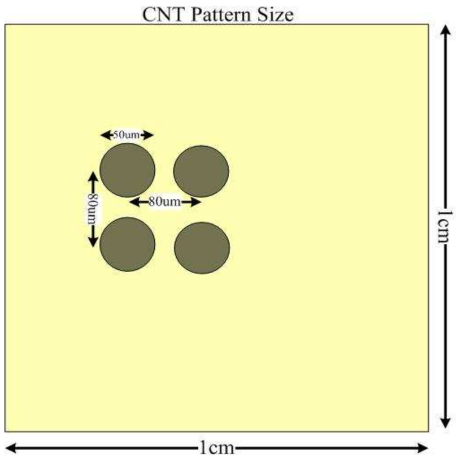

Fig. 1 Illustration of CNT pattern Size

Measurement Procedures

Seven carbon nanotubes samples are used in the measurement tests; in which numbers 1–3 are high density pattern-less carbon nanotubes; their grown heights are 64µm, 80µm and 100µm respectively. In Fig. 2, it is the SEM of the 64um nanotubes with tube's diameter of 25nm- 29nm; the SEM of the other tube's diameters is shown in Fig. 3. Numbers 4–7 nanotubes are pattern-grown carbon nanotubes with grown heights of 85µm, 40µm, 27um and 20um and shown in Fig. 4.is the SEM of the nanotubes with grown height of 85µm.

.In the return loss measurement test an optical spectrum analyzer (OSA) is used to generate a wideband optical source with wavelength in the range 1150nm-1755nm; it is then transmitted to the circulator and vertically incidents on the carbon nanotubes samples. Then the light reflected from the device under test passes through the circulator, optical fiber and reached at the OSA for the analysis of its spectrum contents; the path loss during the measurement has been compensated and adjusted from the mirror-built device under test.

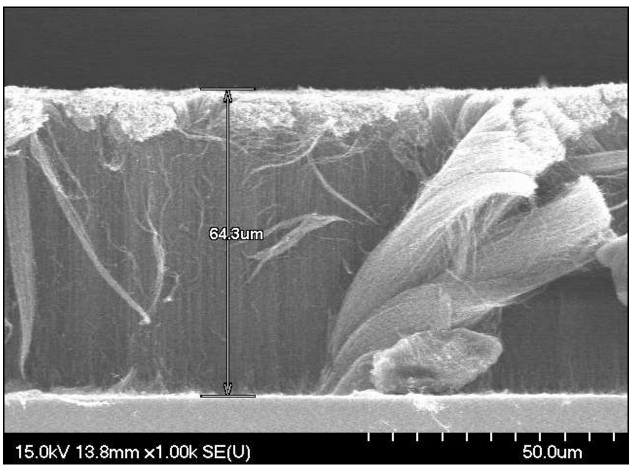

Fig. 2 64 um Grown Height Pattern-less Carbon Nanotubes

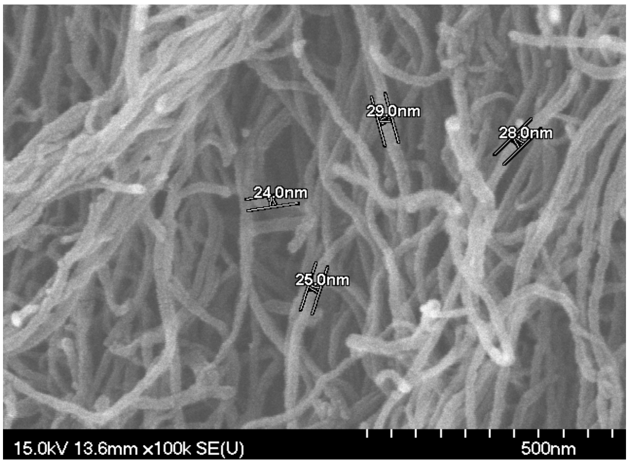

Fig. 3 Pattern- less CNT with Different Diameter Sizes

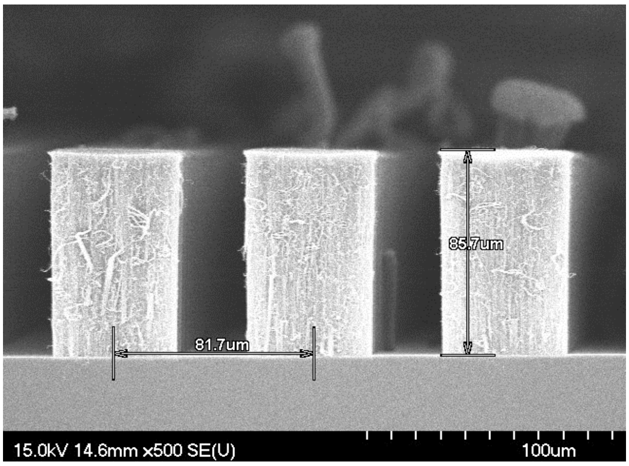

Fig. 4 Pattern-grown CNT with Grown Height 85 um

Measurement Results

Pattern-less CNT Tested as a Black Body Absorber. The spectral power measurements with CNT implemented as a black body absorber have the results as shown in Fig. 5and 6. In Fig. 5, it is the spectral analyzer measurement result for the number 2 CNT (pattern-less CNT with 80μm height) while in Fig. 6, it is the spectral analysis result from the mirror-formed reflector. From Fig. 5, it observes that when number 2 CNT is implemented as a reflector its reflected optical energy is quite small and it also suffers large noise interference. However when it is implemented as a mirror-formed reflector its measurement result, as shown in Fig. 6, has reflected optical energy of -40 dBm with path loss of 5 dB and it suffers quite small noise interference.

The measurement results for numbers 1–3 CNTs are tabulated in Table 1, it shows that with grown heights of 64.3 um, 79.4 um and 96.8 um pattern-less CNTs they have the same return loss of 45 dB and this is equivalent to a reflectivity of 0.56%.

Linear Relationship Test between Return Loss and CNT Grown Height in Pattern-grown CNTs. The return losses of pattern-grown CNTs versus different CNT grown heights are measured; their test results are listed in Table 2 and also plotted in Fig. 7. From this figure we can conclude that there actually exists a linear relationship between the CNT grown heights versus their associated return losses. In our fabrication the grown density of the pattern-grown CNTs are the same for all grown heights and this is coincident with the results as reported in the literatures that the product of the grown height of a CNT with its grown density is linearly proportional to its average emissivity.

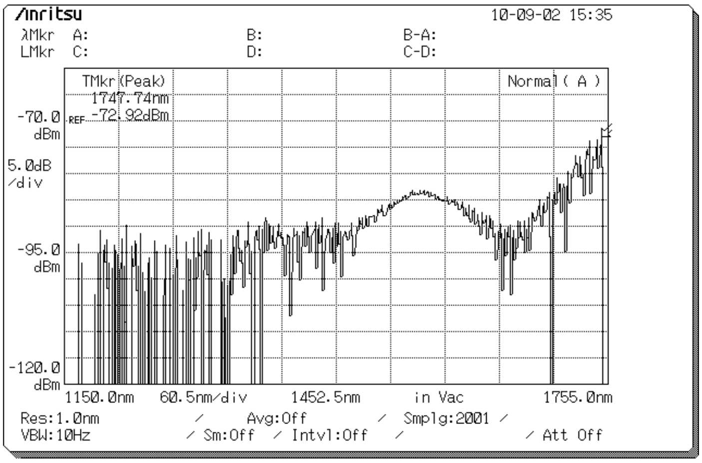

Fig. 5 Spectral Measurement of No. 2 CNT as a Reflector Plane

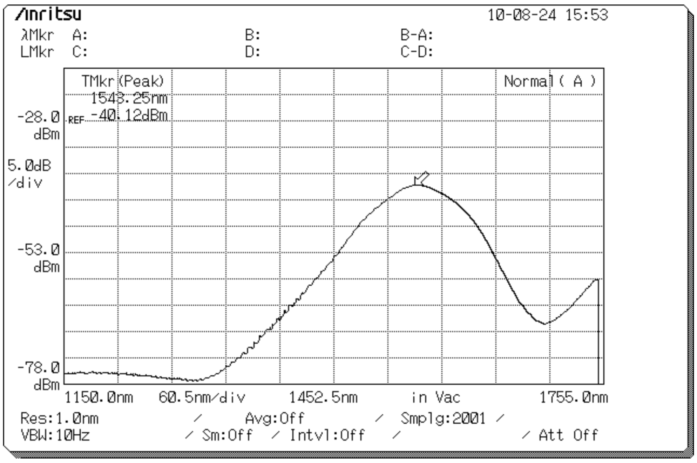

Fig. 6 Spectral Measurement of the Mirror-formed Reflector as a Reflector Plane

CONCLUSIONS

From measurement results it concludes that the high density pattern-less grown multiwall CNT has absorption effect better than that fabricated from a single-wall CNT and it can be utilized as a perfect absorber. The return loss of a pattern-grown multiwall CNT is linearly propositional to the grown height of the CNT and then the pattern-grown CNT can be implemented in the applications as an attenuator with fixed absorption rate.

Table 1 Measured Absorption Rate of Pattern-less CNTs

No	Height	Return Loss	Reflectivity	Absorption Rate
1	64.3 um	45 dB	0.56%	99.44%
2	79.4 um	45 dB	0.56%	99.44%
3	96.8 um	45 dB	0.56%	99.44%

Table2 Measured Return Loss and Reflectivity of Pattern-grown CNTs

No	Height	Spacing	Cylinder Diameter	Return Loss	Reflectivity
4	85.7 um	30 um	50 um	20 dB	10%
5	42.3 um	30 um	50 um	12 dB	25.12%
6	27 um	30 um	5 um	9 dB	35.48%
7	19.8 um	30 um	50 um	8 dB	39.81%

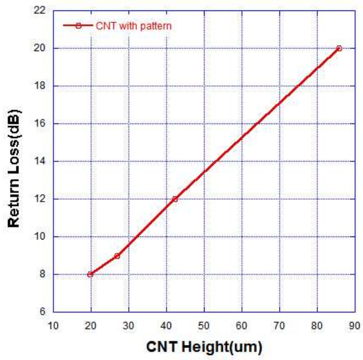

Fig. 7 Liner Relationship between the Grown Height vs. Return Loss of a Typical Pattern-grown CNT

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